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(54) [Title of the Invention] ACTIVE MATRIX LIQUID CRYSTAL DISPLAY DEVICE AND MANUFACTURING METHOD THEREOF

(57) [Abstract]

[PURPOSE] To prevent contact failure between a TFT electrode and a pixel electrode without increasing the number of manufacturing steps.

[Configuration] A thin film transistor and a peripheral contact electrode are formed over a

transparent electrode, and a passivation film is stacked. Contact holes are formed above the peripheral contact electrode and an electrode of the transistor, in this film, and a metal film is stacked and patterning thereof is performed so that pattern formation of the metal film is performed above a channel portion of the thin film transistor and the contact hole. Here, a light-shielding film above the channel portion and the metal film above the contact hole are formed in different islands so that the light-shielding film above the channel portion comes to be floating. Finally, a transparent conductive material is stacked and patterning thereof is performed to form a pixel electrode. At the same time, pattern formation of a transparent conductive layer is performed above the light-shielding film, as well.

[Scope of Claim]

[Claim 1] An active matrix liquid crystal display device including a thin film transistor substrate including an allay of thin film transistors each including a gate electrode, a gate insulating film, a semiconductor layer, and drain and source electrodes formed over a transparent substrate, the active matrix liquid crystal display device characterized in that a metal light-shielding film which shields a channel portion of the thin film transistor against light and a pixel electrode are provided above a passivation film so that the metal film is interposed between the source (drain) electrode and the pixel electrode.

[Claim 2] The active matrix liquid crystal display device according to claim 1, characterized in that the metal light-shielding film is covered with a transparent conductive film.

[Claim 3] The active matrix liquid crystal display device according to claim 1 or 2, characterized in that the metal light-shielding film is separated from the pixel electrode and is electrically floating.

[Claim 4] The active matrix liquid crystal display device according to claim 1, 2, or 3, characterized in that a surface of the semiconductor layer of the thin film transistor is inactivated by hydrogen plasma treatment.

[Claim 5] A manufacturing method of an active matrix liquid crystal display device, characterized by comprising a step of selectively forming a gate electrode and a signal line over a transparent substrate; a step of selectively forming a gate insulating film, a first semiconductor layer, and a second semiconductor layer over the substrate; a step of forming drain and source electrodes by

depositing a metal film and performing patterning thereof; a step of forming contact holes above a peripheral terminal portion and the source and drain electrodes by growing a passivation insulating film and performing patterning thereof; a step of forming a metal film in the channel contact hole by depositing a metal and performing patterning thereof; and a step of forming a pixel electrode by using a transparent conductive film.

[Claim 6] The manufacturing method of the active matrix liquid crystal display device according to claim 5, characterized in that the contact holes are formed in the passivation film and, at the same time, the gate insulating film is selectively removed so that a part of the signal line is exposed.

[Claim 7] The manufacturing method of the active matrix liquid crystal display device according to claim 5 or 6, characterized in that hydrogen plasma treatment is performed on the semiconductor layer prior to the formation of the passivation film so that a back channel of a transistor is inactivated.

[Detailed Description of the Invention]

[0001]

[Field of Industrial Application] The present invention relates to a liquid crystal display device and relates, in particular, to an active matrix liquid crystal display device including thin film transistors, and a manufacturing method thereof.

[0002]

[Conventional Art] FIG. 6(a) is a cross-sectional diagram and FIG. 6(b) is a plan diagram showing a general outline of a conventional active matrix liquid crystal display device including thin film transistors. This active matrix liquid crystal display device is composed of a thin film transistor (TFT) substrate 18 and a counter substrate 19, and has a structure in which twisted nematic (TN) liquid crystals are interposed between the substrates. The TFT substrate 18 includes a pixel electrode 13, a signal line 22, and a scan line 21 corresponding to each pixel formed in matrix over a glass substrate 1, and a thin film transistor (TFT) 23 provided for each pixel electrode. The counter substrate 19 includes a transparent electrode 24, and a colored layer 25 of R, G, or B and a light-shielding layer 26 for shielding against light corresponding to each pixel.

[0003] FIG. 7 shows a manufacturing method of such a TFT substrate. A first metal film made of Cr, W, Ta, Al, or the like is deposited on the glass substrate 1 by a sputtering method or the like, and

patterning thereof is performed, whereby forming a gate electrode 2 and a peripheral contact electrode 3 for each signal line and scan line (FIG. 7(a)). Next, a gate insulating film 4 made of SiNx or the like and a non-doped amorphous silicon (a-Si) film 5 and n+a-Si 6 doped with phosphorus at a high concentration are continuously grown by a plasma CVD method, and after that, patterning of the n+a-Si 6 and the a-Si 5 are performed into island shapes (FIG. 7(b)). Next, patterning of the gate insulating film is performed so that only the gate insulating film 4 above the peripheral contact electrode 3 formed of the first metal film is selectively removed (FIG. 7(c)). Next, a second metal film made of Cr, W, Ta, Al, or the like is deposited by a sputtering method or the like and patterning thereof is performed, whereby forming a signal line, a drain electrode 7, and a source electrode 8 (FIG. 7(d)). A part of the signal line is connected to the contact electrode 3. Further, a transparent electrode made of indium tin oxide (ITO) or the like is deposited and patterning thereof is performed, whereby forming the pixel electrode 13.

[0004] Next, the n+a-Si above a channel portion 15 of a TFT is removed by etching using the source and drain electrodes 8 and 7 as masks (FIG. 7(e)). Further, in the case of a projector or the like which is operated under strong light in particular, it is necessary to provide a light-shielding layer above a TFT as well, and therefore, a metal light-shielding film 11 made of Cr, W, Ta, Al, or the like is formed, and patterning thereof is performed (FIG. 7(g)).

[0005] As described above, in a manufacturing method of a conventional channel etch type thin film transistor with a light-shielding film, patterning steps correspond to respective steps so that the number of patterning steps is seven.

[0006] In the above-described structure, since the signal line 22 and the pixel electrode 13 are formed in the same layer, the number of shorts between the pixel electrode 13 and the signal line 22 are increased due to etching residue or the like unless a distance x (see FIG. 6(b)) between the signal line 22 and the pixel electrode 13 is as large as approximately 10 μm to 20 μm. Therefore, the pixel area is reduced, and, in the case of a diagonal 25 cm VGA panel, the aperture ratio is reduced to 50% to 60%.

[0007] For solving the problem, in Japanese Published Patent Application No. Sho64-68729, as shown in FIG. 8, after the drain and source electrodes 8 and 7 are formed and a part thereof corresponding to a channel is carved out, a passivation film 9 is formed and a contact hole 10 is

formed in the film 9, and after that, the pixel electrode 13 is formed. The pixel electrode 13 is, accordingly, connected to the source electrode 8 through the contact hole 10 provided in the passivation film 9.

[0008] In this case, since the signal line 22 (7, 8) and the pixel electrode 13 exist in different layers, the distance between them can approach from 0 μm to 2 μm, and, in the case of the diagonal 25 cm VGA panel, the aperture ratio is increased to 60% to 70%.

[0009] However, there are problems in that disconnecting of the pixel electrode 13 in the contact hole 10 portion occurs and contact failure between the source electrode 8 and the pixel electrode 13 occurs.

[0010] Therefore, a technique in which the contact hole portion 10 has a two-layer structure of the transparent pixel electrode 13 and a metal layer 12, as shown in FIG. 8 using reference numeral 12, has been disclosed in Japanese Published Patent Application No. Sho 4-68729. In this case, as compared with the case where interlayer separation is not performed, the number of patterning steps is increased by one for a patterning step of the metal layer in the contact portion so that the number of patterning steps is eight.

[0011] In order to suppress such an increase in the number of patterning steps, in Unexamined Utility Model Application No. Hei1-104051, as shown in FIG. 9, a TFT in which the metal layer 12 of the contact hole portion 10 is formed of the same metal film as the metal light-shielding film 11, that is, the light-shielding film 11 is also used as the contact metal layer 12 has been disclosed. In this case, the metal layer 12 is formed by being patterned into an island shape within the contact hole and above a channel region of the TFT.

[0012] In such a TFT, the number of patterning steps is seven because patterning of the light-shielding film 11 and the metal layer 12 is performed at the same time.

[0013]

[Problems to be Solved by the Invention] As set forth above, it has been proposed that the pixel electrode be formed so as to overlap with the source electrode in order to improve the aperture ratio, and it has been proposed that the two-layer structure of the transparent pixel electrode layer 13 and the metal layer 12 be employed in the contact hole 10 in order to solve the problem of contact failure in this case.

[0014] However, from the results of actual experimental production, as a cause of contact failure, in addition to disconnecting of the pixel electrode 13 in the contact hole 10 portion, contact failure between the second metal film, which is the source electrode 8, and the transparent pixel electrode 13 made of ITO or the like was recognized. It is thought that this is because when the passivation film 9 is formed by plasma CVD or the like after the drain and source electrodes 7 and 8 are formed of Cr or the like, oxidized Cr is formed on the metal surface, ohmic contact is not obtained if a semiconductor film of ITO or the like is stacked so that contact characteristics become extremely poor.

[0015] Therefore, in the methods shown in FIGS. 8 and 9, in order to obtain good contact between the source electrode 8 and the pixel electrode 13, a step of removing the metal oxide film on the surface of the source electrode 8 by etching or a reverse sputtering method is required. This complicates the manufacturing process and decreases the yield.

[0016] Further, in FIG. 9, although the light-shielding film 11 is also used as the metal layer 12 in the contact portion, in this case, an MIS structure is formed by the light-shielding film 11, the passivation film 9, and the a-Si film 5, and a so-called back channel is formed. Therefore, respective electrical properties of the TFT for when the pixel electrode 13 is in a positive frame and when it is in a negative frame are asymmetrical particularly on an off side as shown in FIG. 2, which causes display failure of a panel due to off characteristics of a TFT or display failure due to a DC characteristics being applied to liquid crystals; therefore, there has been a problem with panel display.

[0017] Moreover, since the metal light-shielding film 11 (12) is the top layer and is directly in contact with liquid crystals through an alignment material, there has been a problem with chemical instability.

[0018] In view of these points, it is an object of the present invention to provide a chemically stable active matrix substrate, which can be manufactured with reduced contact failure between source and pixel, at low cost, and at a high yield without increasing the complexity of a process in the above-described drain-pixel interlayer separation TFT process, and a manufacturing method thereof.

[0019]

[Means To Solve the Problems] In order to achieve the above-described object, the present invention provides an active matrix substrate, which is characterized in that in a thin film transistor substrate including an allay of thin film transistors each including a gate electrode, a gate insulating film, a semiconductor layer, and drain and source electrodes formed over a transparent insulating substrate, a metal light-shielding layer for shielding a channel portion of each transistor against light and a pixel electrode are provided above a passivation film which covers the thin film transistor substrate so that contact between the source and the pixel electrode is formed by the metal light-shielding film and the pixel electrode in this order.

[0020] Further, the present invention provides a manufacturing method of an active matrix substrate, which is characterized by comprising a step of forming a gate electrode over a transparent substrate; a step of continuously growing a gate insulating film, a non-doped semiconductor layer, and a low-resistance semiconductor layer, and performing patterning of the semiconductor layers; a step of removing the gate insulating film above a scan line and signal line drawing portion; a step of forming drain and source electrodes by depositing a metal film and performing patterning thereof; and a step of removing a passivation film above the scan line and signal line drawing portion and, at the same time, forming a contact hole above the source electrode by growing an insulating film and performing patterning thereof.

[0021]

[Embodiments] In order to clarify the above-described and other objects, characteristics, and advantages of the present invention, embodiments of the present invention are described below with reference to drawings.

[0022] FIG. 1 is cross-sectional diagrams of an active matrix liquid crystal display device of a first embodiment of the present invention, shown in order of manufacturing steps. In this embodiment, first, a first conductive film made of Cr, W, Ta, Al, or the like is deposited to a thickness of 100 nm to 300 nm on the transparent insulating substrate 1 made of glass or the like by a sputtering method or the like, and patterning thereof is performed by a photolithography method, whereby forming the gate electrode 2 and the scan line and peripheral contact electrode 3 (FIG. 1(a)).

[0023] Next, the gate insulating film 4 made of SiNx or the like to a thickness of 200 nm to 600 nm, the non-doped a-Si film 5 as a channel layer to a thickness of 100 nm to 400 nm, and the n+a-Si

film 6 doped with phosphorus as a contact layer to a thickness of 10 nm to 100 nm are continuously formed by a plasma CVD method or the like, and patterning of each semiconductor layer into an island shape is performed (FIG. 1(b)).

[0024] Next, a part of the gate insulating film 4 above the scan line and signal line drawing portion 3 is removed (FIG. 1(c)).

[0025] Next, after a second conductive film made of Cr, W, Ta, Al, or the like is deposited to a thickness of 100 nm to 300 nm by a sputtering method or the like, patterning of the second conductive film and the contact n+a-Si layer 6 is performed, whereby forming the signal line, and the drain electrode and the source 7 and 8 (FIG. 1(d)).

[0026] Next, the passivation film 9 made of SiNx or the like is formed to a thickness of 100 nm to 300 nm by a plasma CVD method or the like, and the passivation film in the scan line and signal line drawing portion 3 is removed and, at the same time, the contact hole 10 is formed above the source electrode 8 (FIG. 1(e)).

[0027] Next, a third conductive film made of Cr, W, Ta, Al, or the like is formed to a thickness of 50 nm to 200 nm by a sputtering method, and patterning thereof is performed, whereby forming the metal film 12 above a thin film transistor channel portion 15 and above the contact hole portion 10 (FIG. 1(f)). Here, the light-shielding film 11 above the channel portion 15 and the metal film 12 above the contact hole are separated from each other, and therefore, the light-shielding film 11 above the channel comes to be floating in an operating state. If the light-shielding film 11 and the metal film 12 are continuously formed, an MIS structure is formed by the metal light-shielding film 11, the passivation film 9, and the non-doped a-Si film 5, and respective current properties of the TFT for when the pixel electrode 13 is in a positive frame and when it is in a negative frame are asymmetrical particularly for off characteristics as shown in FIG. 2 so that panel display quality deteriorates due to deterioration of off characteristics and a DC voltage being applied to liquid crystals. On the other hand, by the above-described structure, such a problem is prevented.

[0028] Finally, a transparent conductive material such as ITO is deposited by sputtering, whereby performing pattern formation of the pixel electrode 13 (FIG. 1(g)). At the same time, a transparent conductive layer 14 is also left remaining over the light-shielding film 11 by patterning. Accordingly, chemical instability due to direct contact between the light-shielding metal 11 and

liquid crystals is prevented. It is needless to say that the pixel electrode 13 and the conductive layer 14 are separated from each other.

[0029] It could be confirmed that by directly connecting the source electrode 8 and the metal layer 12 in the contact hole between the source and pixel electrode, 8 and 13, as described above, contact failure which occurred in the case of forming the pixel electrode 13 and the metal light-shielding film 12 in this order did not occur and good contact was formed. Although an oxide film is formed on the surface of the electrode 8, the electrode 8 and the metal layer 12 are in contact with each other with a resistance of several ohms when the metal layer 12 is directly formed by sputtering, although the reason thereof is not clear. Further, a light-shielding effect is sufficient and the TFT structure is sustainable even for use under strong light, such as in the case of a projector. Further, the number of patterning steps is 7 PR, which is similar to the conventional example.

[0030] Next, a second embodiment of the present invention is described with reference to FIG. 3. Similar to the first embodiment, the gate electrode 2 is formed (FIG. 3(a)), the gate insulating film 4, the non-doped a-Si film 5, and the low-resistance n+a-Si film 6 are continuously formed, and patterning of the semiconductor layers is performed into island shapes (FIG. 3(b)). Next, without removing the gate insulating film above the scan line and signal line drawing portion 3, the second metal film is stacked, and patterning of the second metal film and the n+a-Si film is performed, whereby forming the signal line, the drain electrode 7, and the source electrode 8 (FIG. 3(c)). Next, the passivation film 9 made of SiNx or the like is stacked, and the contact hole 10 above the source electrode 8 is formed and, at the same time, the insulating layer in the scan line and signal line drawing portion 3 is removed (FIG. 3(d)). At this time, although only the passivation film 9 with a thickness of about 200 nm is removed for forming the contact hole 10 above the source electrode 8, the passivation film 9 with a thickness of about 200 nm and the gate insulating film 4 with a thickness of about 600 nm both need necessarily be removed above the drawing portion, so that it is necessary to optimize an etching condition, e.g., by performing dry etching using O_2 and CF_4 gases for removing the insulating film, so that the contact hole portion cones to be a tapered shape. After that, the metal light-shielding films 11 and 12, which also form contact between the source electrode 8 and the pixel electrode 13, are formed (FIG. 3(e)), patterning thereof is performed, and

finally, the pixel electrode 13 is formed of a transparent conductive material such as ITO (FIG. 3(f)). In this case, since patterning in the scan line and signal line drawing portion 3 and patterning of the passivation film are performed at the same time, the number of patterning steps is 6 PR.

[0031] Next, a third embodiment of the present invention is described with reference to FIG. 4. In this embodiment, hydrogen plasma treatment is performed prior to the film formation step of the passivation film 9 of the above-described first and second embodiments (FIG. 4(a)). An object of this is to inactivate a back channel 16 of a TFT by hydrogen plasma treatment in order to prevent deterioration in display quality of a panel due to an increase in off-current of the TFT which occurs in accordance with charging of the metal film 11 and turning the back channel 16 of the TFT on when a metal film made of Cr or the like is used as a light-shielding film. This is because inactivation of the back channel 16 of the TFT is performed. According to this, H_2 is absorbed in the form of SiH_2 on an a-Si back channel 16 side, and an Si network becomes coarse as shown in FIG. 4(b), whereby the back channel 16 is inactivated.

[0032] FIG. 5 shows plasma time dependence of back channel characteristics of the TFT in the case where hydrogen plasma treatment is performed under the following conditions: at a hydrogen flow rate of 2000 sccm, an RF power of 250 W, and a pressure of 200 Pa. Plasma time dependence of back channel characteristics of the TFT in the case where hydrogen plasma treatment is thus performed is shown. As a result of this, by performing hydrogen plasma treatment for equal to or more than 30 seconds, the back channel 16 is inactivated and even if an MIS structure is formed by the metal light-shielding film 11, the passivation film 9, and the a-Si film 5 on the back channel 16 side, off-current characteristics of the TFT are stabilized, and display quality of the panel is improved.

[0033]

[Effect of the Invention] As described above, an active matrix substrate according to the present invention includes a thin film transistor including a gate electrode, a gate insulating film, a semiconductor layer, and drain and source electrodes; a passivation film which covers the thin film transistor; and a metal light-shielding layer which shields a channel portion of the TFT against light and a pixel electrode formed above the passivation film. Further, contact between the source and pixel electrodes is formed of two layers by using a light-shielding film metal and a pixel transparent

conductive material in this order.

[0034] Therefore, according to the present invention, a product in which contact between source and pixel electrodes, which becomes a problem in a drain-pixel interlayer separation TFT panel, can be adequately obtained, in which pixel defects are reduced, and of which properties are excellent can be manufactured at a high yield and at low manufacturing cost.

[0035] Further, by separating the metal light-shielding layer from the source such that the metal light-shielding layer comes to be floating, off characteristics of the TFT can be prevented from being asymmetric in positive and negative frames of each pixel, and display quality of the panel can be improved.

[Brief Description of the Drawings]

[FIG. 1] Cross-sectional diagrams of steps for showing a manufacturing method of a thin film transistor used in an active matrix liquid crystal display device according to the first embodiment of the present invention.

[FIG. 2] A comparison of current properties of a TFT between the case where the metal light-shielding layer is connected to the source electrode and the case where the metal light-shielding layer comes to be floating.

[FIG. 3] Cross-sectional diagrams of steps for showing a manufacturing method of a thin film transistor according to the second embodiment of the present invention.

[FIG. 4] Cross-sectional diagrams of steps for showing a manufacturing method of a thin film transistor according to the third embodiment of the present invention.

[FIG. 5] Hydrogen plasma time dependence of back channel current characteristics of a TFT.

[FIG. 6] A structure of a conventional active matrix liquid crystal display device.

[FIG. 7] Cross-sectional diagrams of steps for showing a manufacturing method of a conventional thin film transistor.

[FIG. 8] A cross-sectional diagram of a thin film transistor disclosed in Japanese Published Patent Application No. Sho 64-68729.

[FIG. 9] A cross-sectional diagram of a thin film transistor disclosed in Unexamined Utility Model Application No. Hei 1-104051.